Department of Defense

Technical Advisory Group

Human Factors in Training

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Intelligent Tutoring Systems Adapted to Satellite and Space Robot Training Simulation

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The Aerospace Corporation

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Overview

- Control Room Evolution
- Bringing the Training and Space Communities Together
- Cognitive Engineering and Conceptual Graph Analysis
- The Software Packages
- Moving onto Space Robots and the Moon and Mars Manned Bases

Intelligent Tutoring System for Space Systems

Why ITS:

•Implement ITS for effective training for space systems personnel – Space systems personnel high turnover rate, and space systems long life.

Advantages:

• Complex systems in capabilities and operation must reduce human error for unforgiving space system operation.

Why now:

•Operators are no longer the developer experts.

•More operators, and more kinds of space systems operated.

•Many geographic locations.

•ITS is now mature enough for space systems.

Early Operators Were Not Trained Because They Were Developers

Photo courtesy of US Air Force

Interim Satellite Control Center in Palo Alto, California, as it looked in 1959. Early operators were developers, and the systems were experimental. Data was collected, but there were no screens.

Satellite Control Rooms Evolved

Photo courtesy of US Air Force

USAF Master Control Room, Sunnyvale, California, 1961

Computers are beginning to evolve in ground stations. Original operators were not trained. They had a manual of how the equipment operated.

World-Wide Facilities Impose a Training Burden

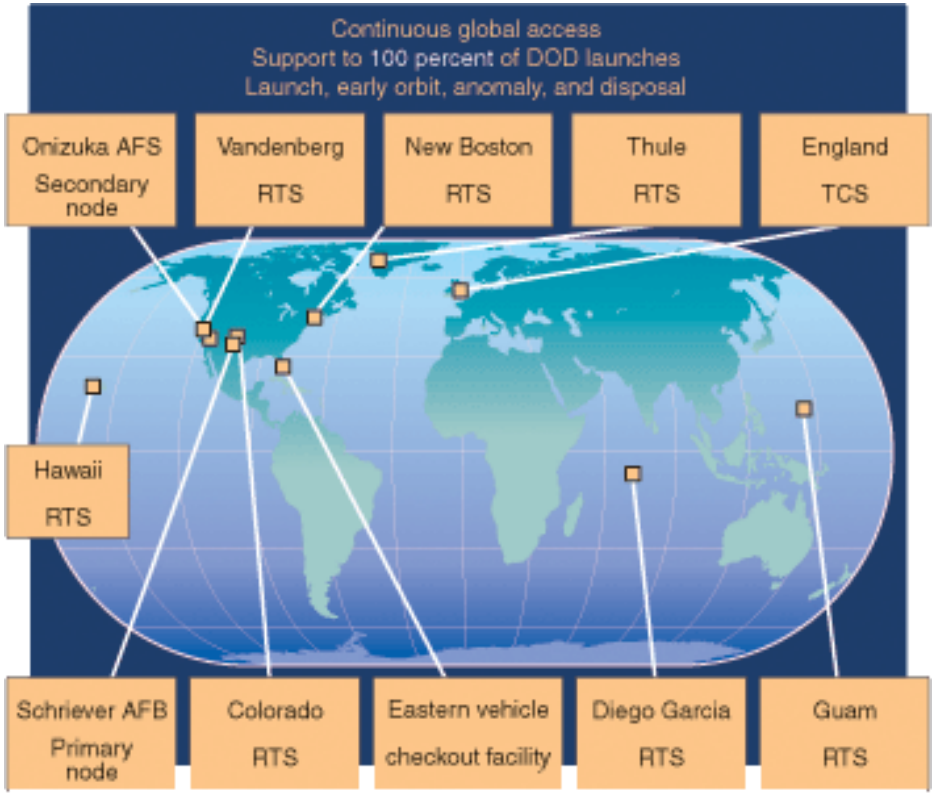


Diagram courtesy of US Air Force

Air Force facilities world-wide – Throughout the years, remote tracking stations have been installed and decommissioned in various locations to suit changing requirements. Lots of facilities, lots more operators, not enough system experts.

Every Organization Operating Satellites Needs Ground Stations

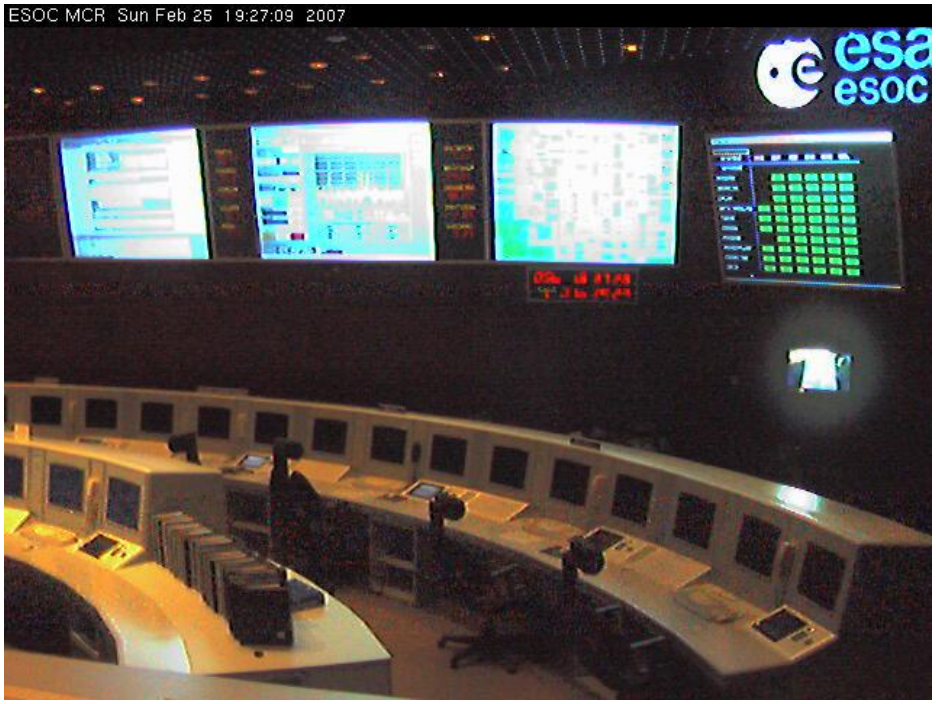


Photo courtesy of European Space Agency

European Space Agency (ESA) European Space Operations Center (ESOC)

ESOC has established a network of ground stations around the world in Sweden, French Guiana, Australia, Belgium, Spain, and Kenya.

The space community is proliferating ground stations. Growing need for operators, and they must be trained on the system they are operating. Not just the U.S.; need is world wide.

The Case for Training the Satellite Operators and Maintainers

- Many more operators required world wide
- Systems are growing in complexity
- Pressure on reducing cost of operations

Early Application of

Intelligent Tutoring Systems (ITS)

- Computer Based Training (CBT)
- Computer Aided Instruction (CAI)
- Intelligent Tutoring Systems (ITS)
  - 1979 – Scholar – South American Geography
  - 1982 – SOPHIE – Electronic Circuit Debugging
  - 1983 – GUIDON – Diagnose Medical Diseases
  - 1984 – LISP Tutor – LISP Programming Language

Off-Line Training is Required
Elements Needed to Begin ITS Development

Identify ITS Elements Needed to Begin ITS Development

Implementation

Courtesy of NASA

Control Mechanisms for a Space Robot

Courtesy of NASA

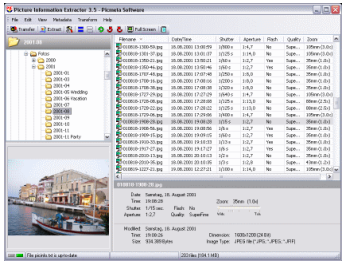
Operation of a Satellite

Need/purpose

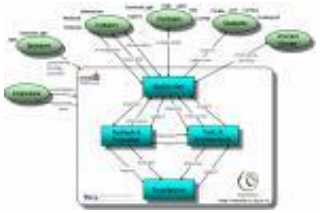
Courtesy of NASA

Operation of a Space Robot

Automated Memory Aids for Operators



Expert Knowledge Database Elements



Learning Model

User's Manual for ITS Documentation

Operations Support Information

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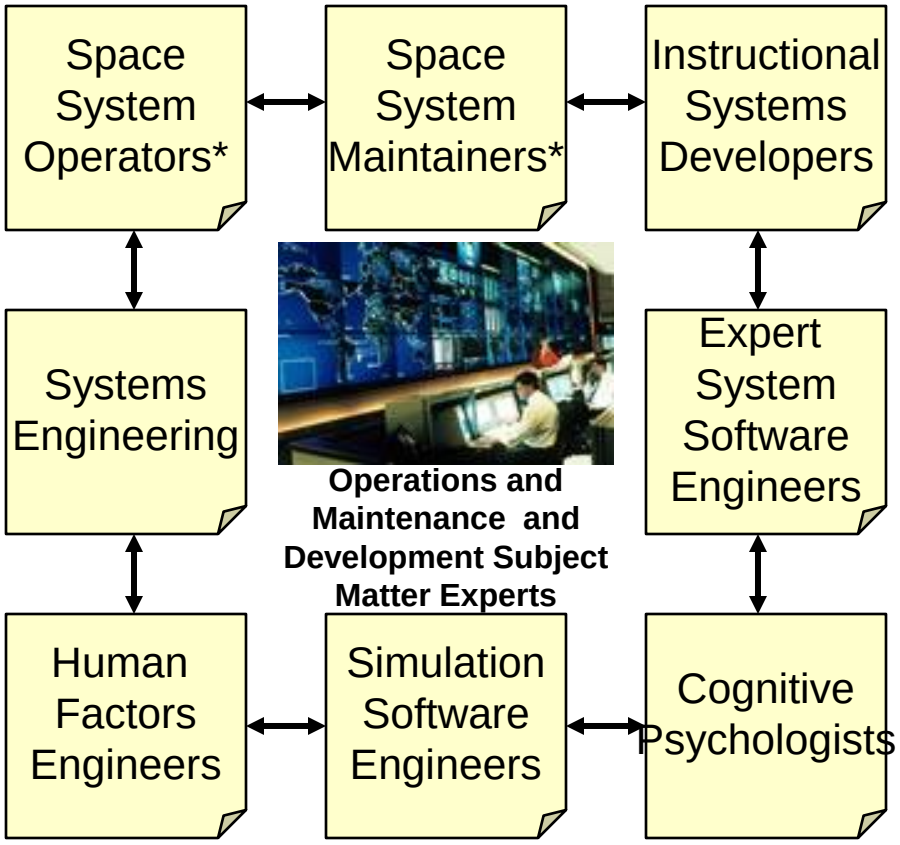
Bringing the ITS Community Together with the Space Community



Make sure all relevant people are included on the team for correct content and execution. Each contributor has a relevant role. Information flow is multi-dimensional and iterative.

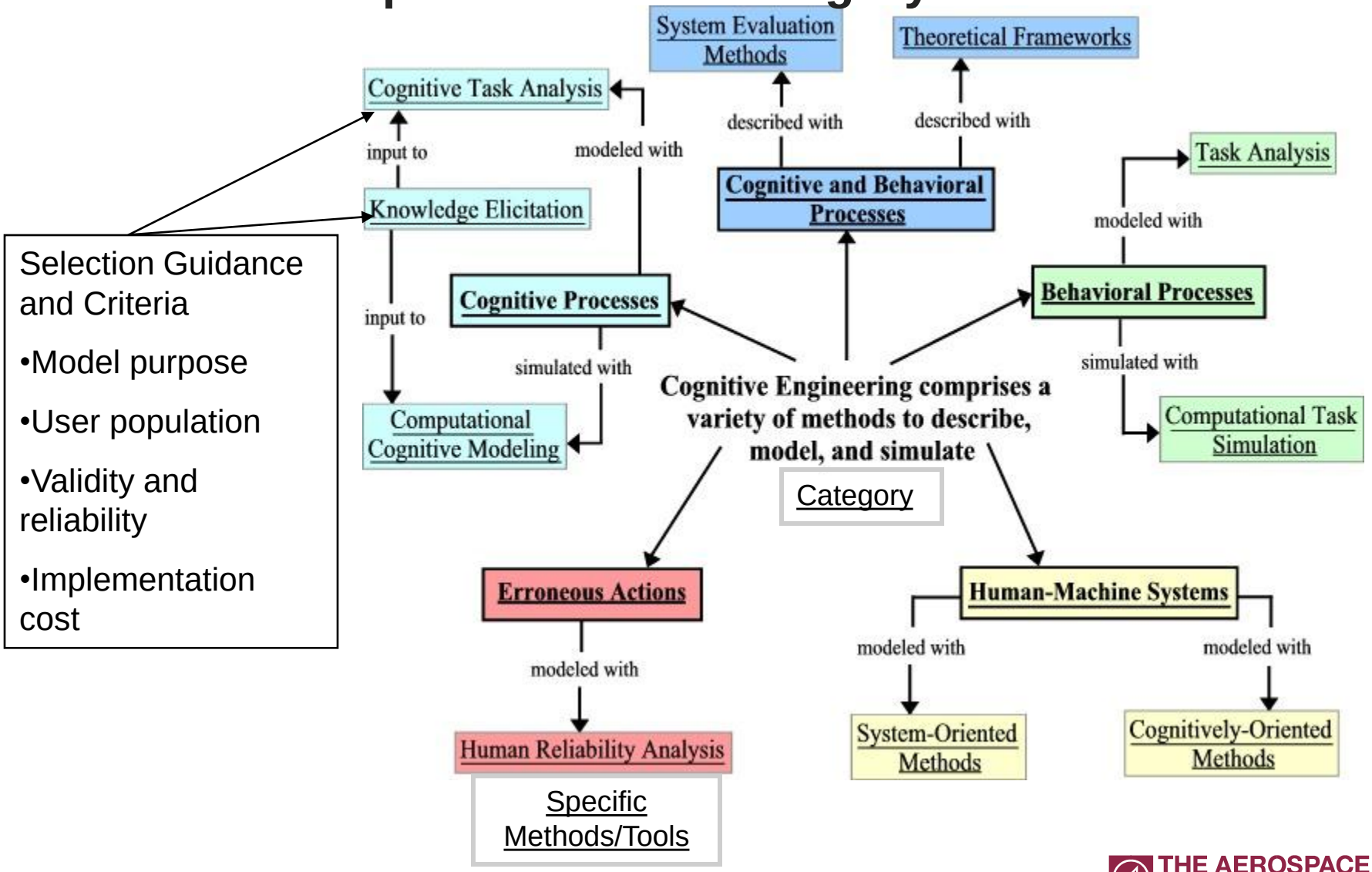
*Have special knowledge and perspective, and may be “Developer” SMEs

Two of the Team Members Perform Cognitive Tasks

•Cognitive Psychologists analyze critical operator and maintainer tasks to develop rules for expert system programming.

•Expert system software engineers implement the rules into instructional software.

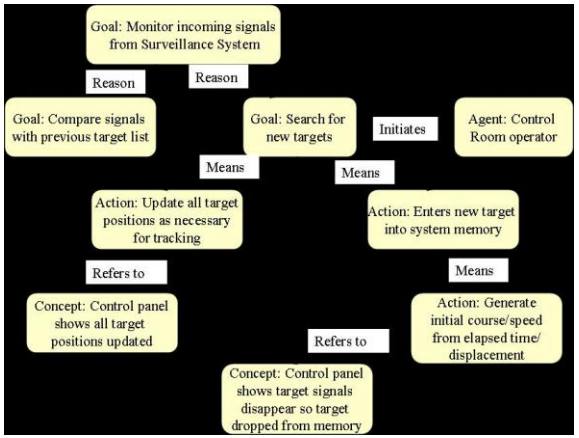
Selection of the Appropriate Category of Analysis Depends on the Purpose, Selecting the Specific Tool or Technique Within the Category is Critical



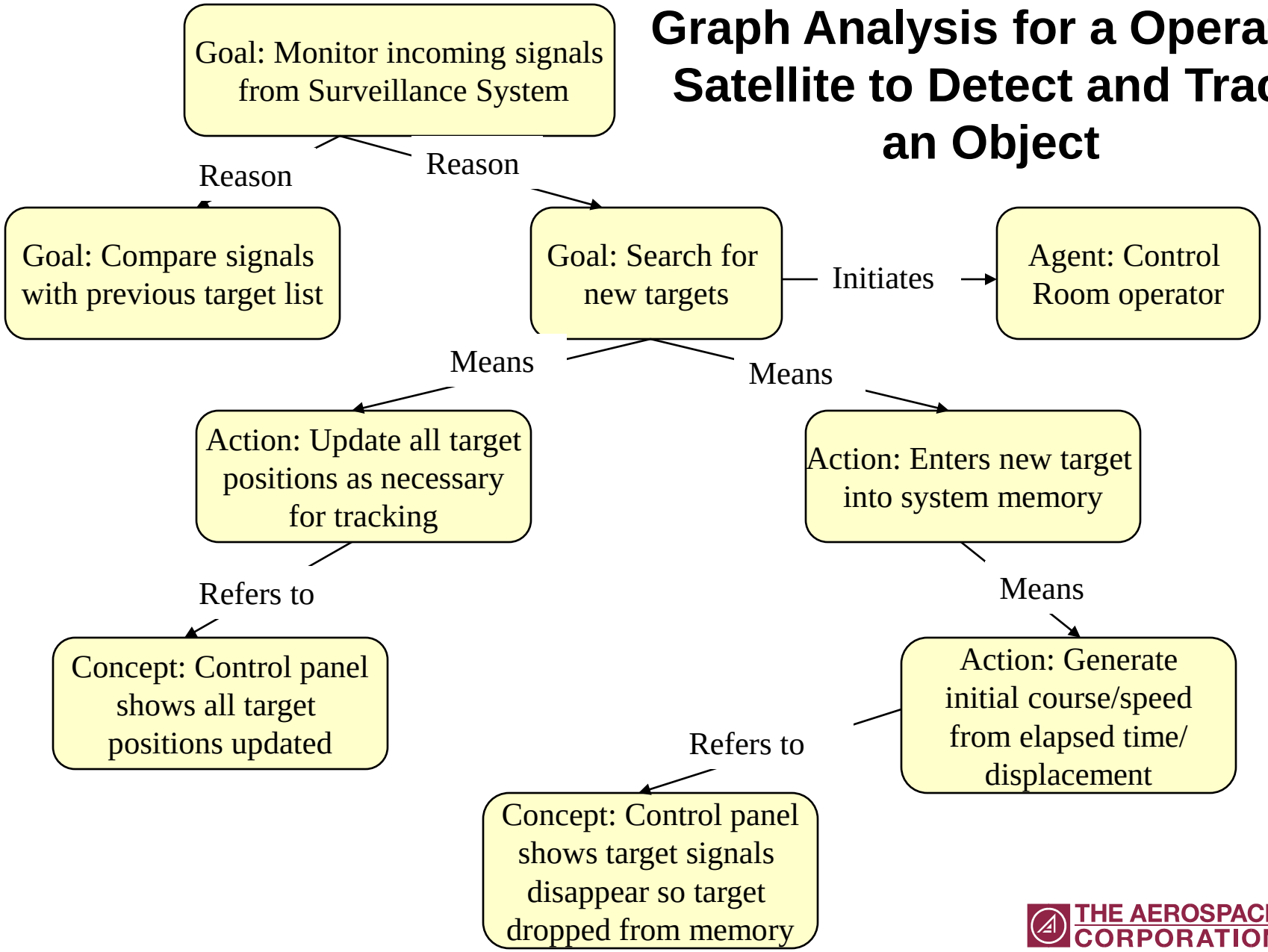
Mental Models, Courtesy of Mitre Corporation, FFRDC

Steps to Develop a Conceptual Graph Analysis

- Perform a task analysis
- Select critical tasks
- Perform a cognitive task analysis
- Construct a rough draft conceptual graph
- Prepare a list of follow-up questions
- Expand the graph
- Review the final graph
- Identify rule sets to program into expert system software shell



Gross-Level Conceptual Graph Analysis for a Operator Satellite to Detect and Track an Object



Not all Expert System Software Shells are Equal

It's Important to Understand Which Characteristics Will be Needed for the ITS Development and Implementation

- Active values (demons) watch slots in other units, and perform actions whenever the slot value changes or is accessed by another frame.
- Ability to interface with training simulation software that simulates space system functions.
- Inference engine includes rule graphs to show how a set of rules might be combined into chains during reasoning.
- Explanations are updated automatically when rules are changed or assertions are retracted.
- There is a method to control the contents of the rule base so that deletion of an assertion causes retraction of other assertions that depend on it.
- Shell is able to interface directly with libraries of text, graphics, or spreadsheets.

Training Management System

- The operator and maintenance trainees should be provided with a spectrum of control.
- The students should be able to develop part of the solution to the task at hand using one approach, and then switch to another modeling approach at mid-task.
- ITS should provide sufficient feedback to enable the students to be aware of the state of the problem-solving process at any point in time.
- Student manuals may need to be prepared to take into account each of the models found within ITS.

Our New Challenges: Moving into New Capability for the Space Industry

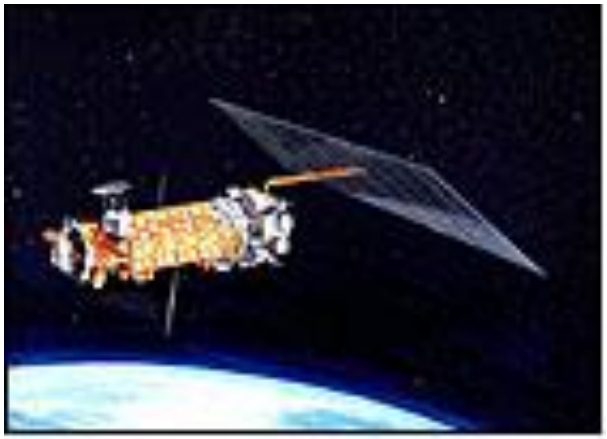
•Space systems continue to be upgraded anytime throughout their lifecycle with software uploads/processing data/ground based upgrades.

•Dynamically update training system based on real experience.

Satellite Operators and Maintainers will Need More Complicated Training

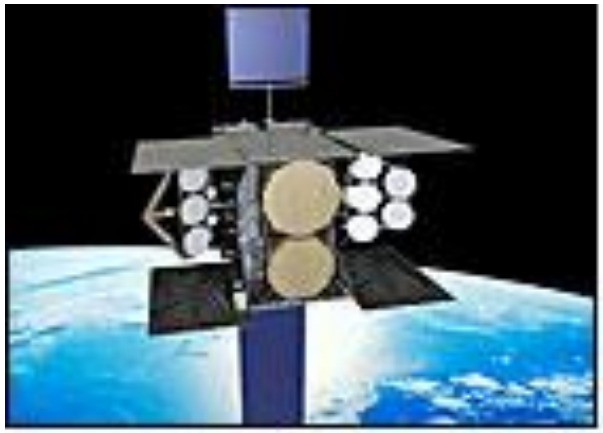
The reduction of Human Error will be extremely important, and some errors will be unrecoverable.

As satellite software evolves, ITS will require constant updating.



Defense Meteorological Satellite Program (DMSP)

DMSP provides high-quality weather images to the U.S. military and civilian communities.



Wideband Gapfiller Satellite Program

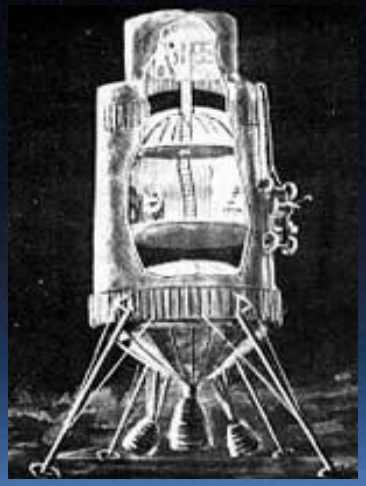
Will augment and eventually replace the communications capabilities of the existing Defense Satellite Communications System

Global Positioning System (GPS)

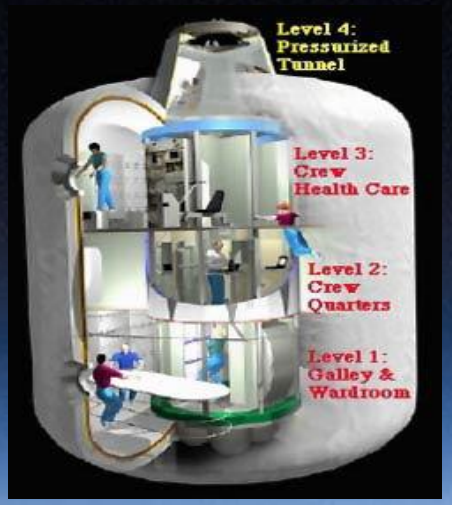
United States, China, and Russia Plan for Lunar Bases

United States

Plans to be back to the Moon in 2020 with people

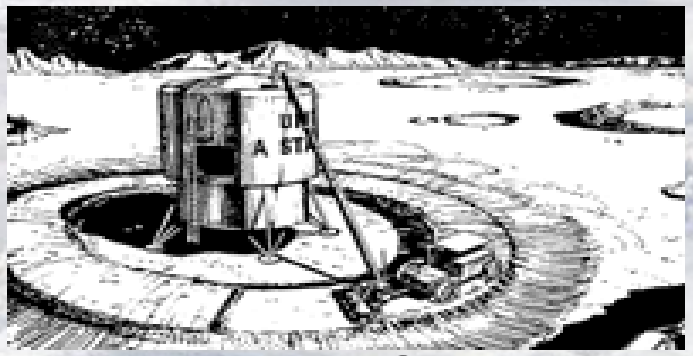


Lunar Base Concept 1966



Inflatable Lunar Base Concept 1992

Artists concepts courtesy of NASA



Lunar Base Concept 1964

Lunar Base Concept 1962

Artist’s concept courtesy of NASA

Lunar Lander

This artist's rendering represents a concept of possible activities during future space exploration missions. It depicts a lander backdropped against the lunar surface.

Artist's concept courtesy of NASA

Lunar Lander

The artist's rendition was created to illustrate some of the landing facilities as they might appear near the end of a Phase II Lunar Base. In this artist's concept the landing has occurred just after dawn. Earth appears over the Rook Mountains in the east across the dry lakebed of Lacus Veris. The lander sits in the middle of 100-meter diameter gravel landing pad where it is being readied for its stay on the lunar surface. Inside, crewmembers are shutting down the flight systems and configuring the lander for its layover. The pressurized vehicle in the foreground is connected to the lander, waiting to take the crew back to the lunar base.

Mars Base Space Robots Need Human Interface

Photo courtesy of NASA

Mars Bases Projected After Moon Bases

Artist's concept courtesy of NASA

Martian outpost where surface experiments are conducted to use natural Martian resources for propulsion. Material processing would provide products that minimize reliance of Earth-to-Mars supply line.

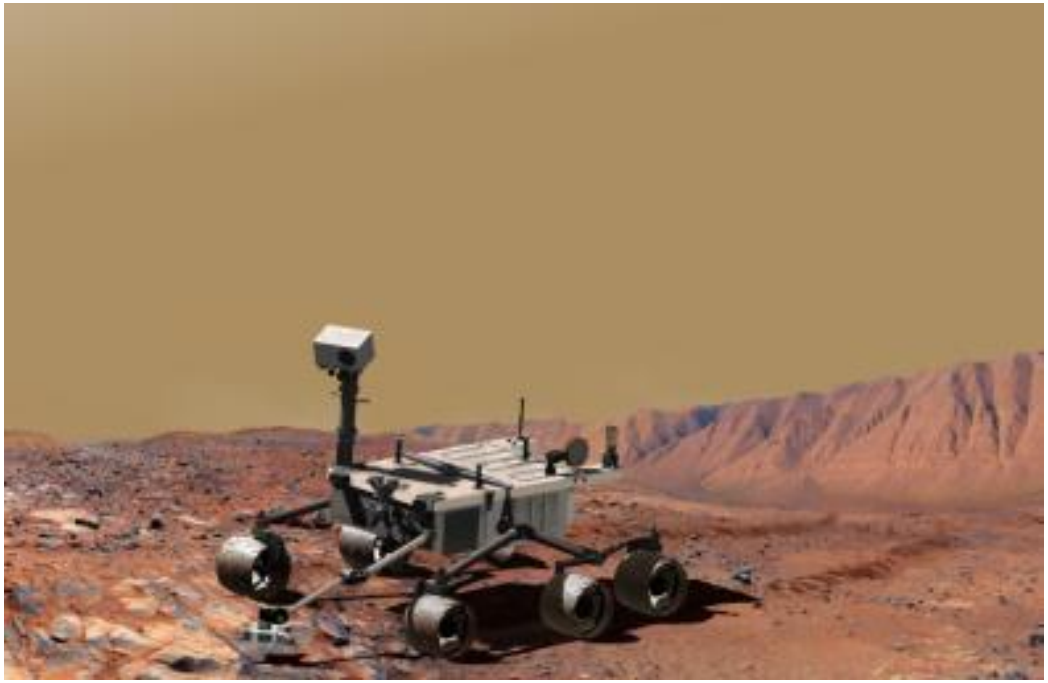
Mars Base Visualization in “Forbidden Planet”

Artist’s concept courtesy of NASA

Mars Lander

The amount of mass that must be lifted from Earth for human missions to Mars can be reduced by as much as 50 percent if a structure called an aerobrake is employed. The Mars landing vehicle depicted here uses a "molly bolt" design that allows the aerobrake to be deployed in a flat shape for atmospheric entry and landing, and then retracted to form a smooth conical shape for ascent.

Mobile Robots are a Special Challenge for Operators

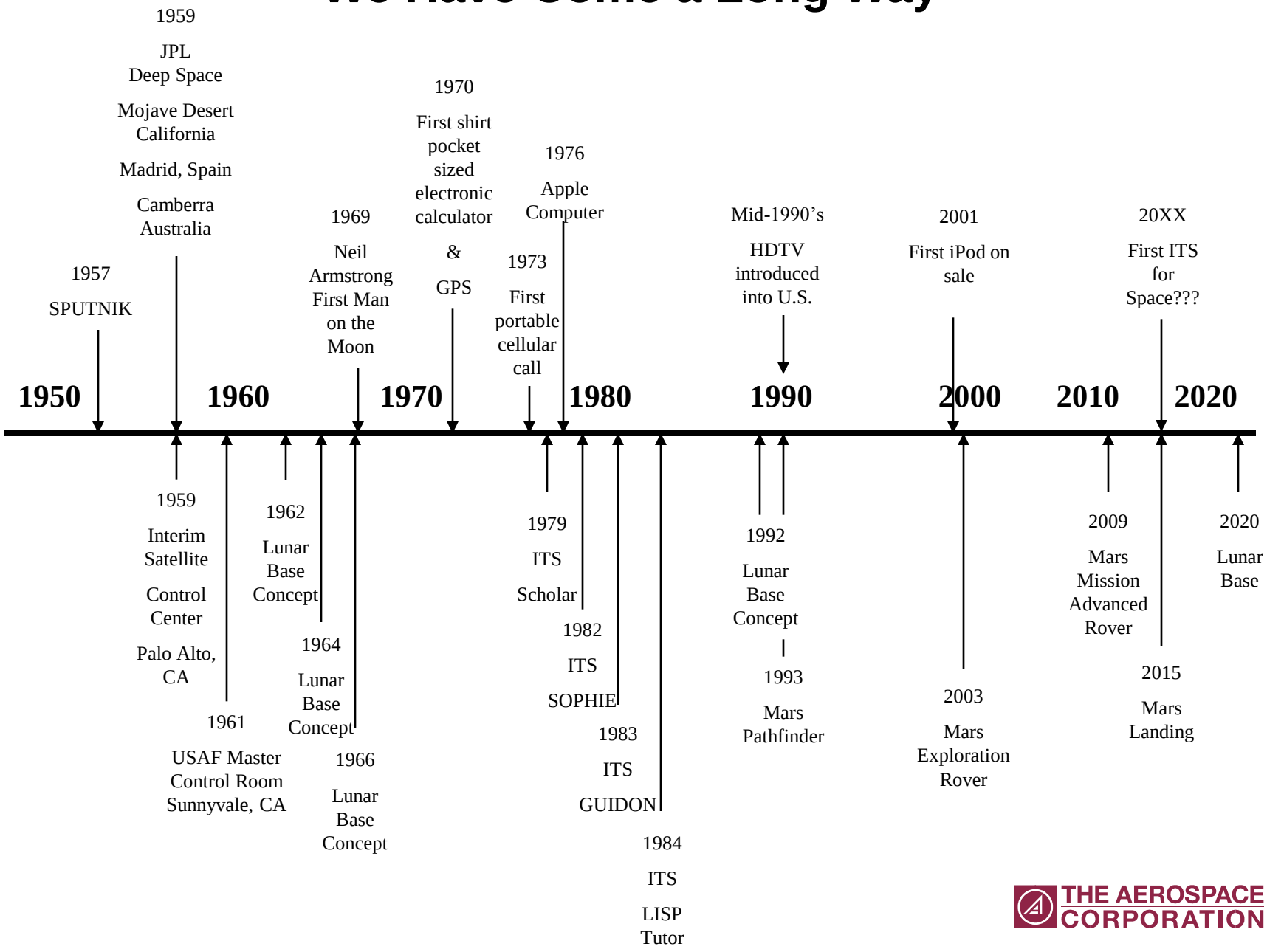


Artist’s concept courtesy of NASA

Mars Mobile Robot

NASA's Mars Science Laboratory, a mobile robot for investigating Mars' past or present ability to sustain microbial life, is in development for a launch opportunity in 2009. This picture is an artist's concept portraying what the advanced rover would look like when examining a rock outcrop on Mars. The arm extending from the front of the rover is designed both to position some of the rover's instruments close to selected targets and also to collect samples for onboard analysis by other instruments.

We Have Come a Long Way



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Activities to Perform Next – Where Are We Going?

- When should ITS be introduced to satellite, space robots, Moon Base, and Mars Base operations?
- What type of cost benefit trade analysis should be performed to determine when to introduce ITS into satellite operator and maintainer training?
- What factors would be used in the cost benefit trades?
- How should the training analysis for Moon and Mars missions be sequenced with the development of hardware, software builds?
- How often will space robots receive software upgrade patches, and how often will the ITS training for operators need software upgrades?

Database Management System Design

•The Database Management System design should enable data models to support logical data independence.

•The Model Based Management System should be able to identify data models that support logical data independence and associated physical data transformations and manipulations.

•Features incorporated into the data description language need to enable errors to be detected at the earliest possible time so that operator/maintainer students will not be affected by errors that occur at a time prior to their use of the Database Management System.

•The Database Management System needs to be designed so that relationships between data models and errors will not occur through concurrent use of the databases by students.

•Software architecture design needs to support a number of students simultaneously having diverse and changing training demands.

Visual Displays – Control Room Displays – Designing for Success Examples

•Displays have multiple color capability.

•Operators can respond quickly to anomalies.

•Information that the controller needs does not disappear from the screen without being deleted or suppressed by controller.

•Essential information is never blocked or obstructed by other information.

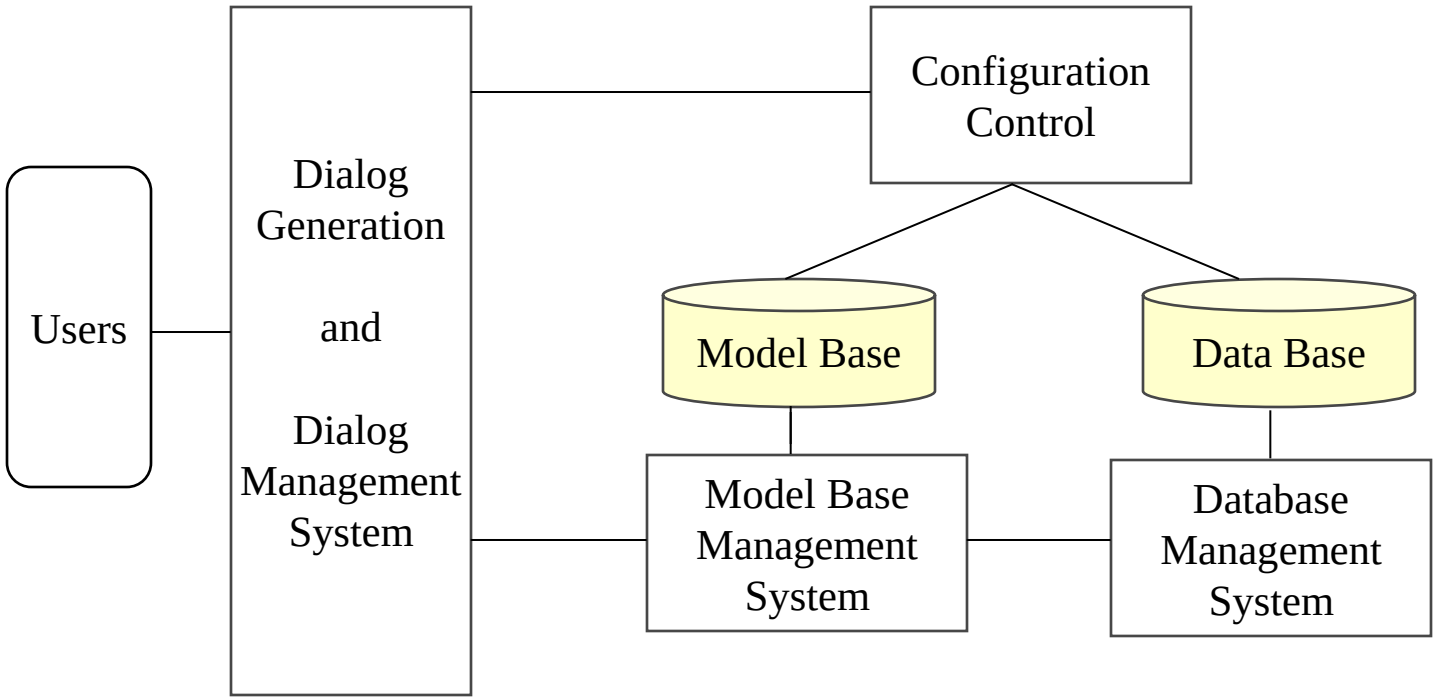
•Display clutter is not a problem.

•All of the symbols chosen for the display are intuitive so that the controller can interpret them quickly and accurately.

•When the meaning of the color is critical, color is used redundantly with another type of visual cue, such as shape, text, or size. For example, all yellow objects have a triangular shape.

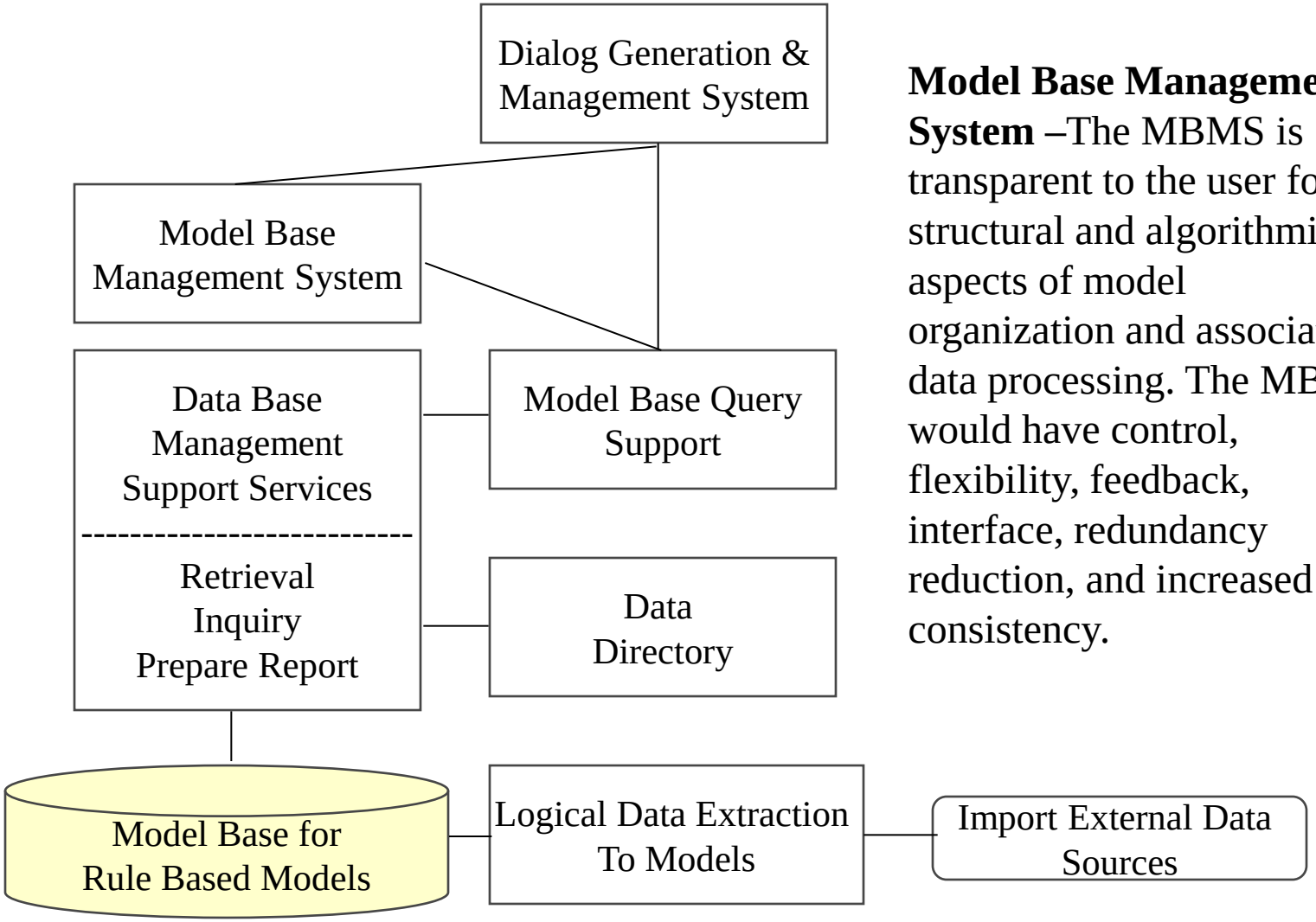
•Saturated (i.e., vivid) red and blue are never presented next to each other.

ITS Management Software Consists of Two Software Databases



The user accesses the program through the Dialog Management System to engage in “What If” analysis. The Model Base Management System (MBMS) supports user selection among multiple models. The MBMS queries the Database Management System (DBMS) to retrieve appropriate data. Configuration Control regulates the Model Base and Database.

The Power of ITS Resides in the Rule Based System



Model Base Management System –The MBMS is transparent to the user for structural and algorithmic aspects of model organization and associated data processing. The MBMS would have control, flexibility, feedback, interface, redundancy reduction, and increased consistency.

Control Room Operators and Maintainers and Satellite Operations

Defense Meteorological Satellite Program (DMSP)
DMSP provides high-quality weather images to the U.S. military and civilian communities.

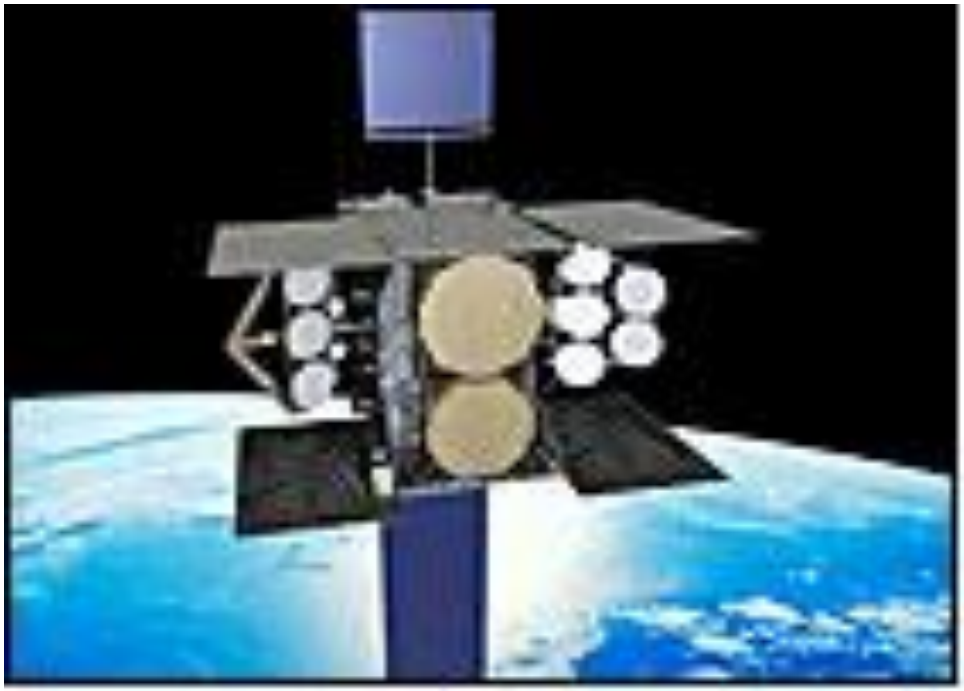
Merge 24 and 25, move picture to 24
Take 3 pictures for one chart quad chart plus satellite words in one quad

Control Room Operators and Maintainers and Satellite Operations

Global Positioning System (GPS)

Delete 26 and 27, and use pictures on other charts.

Control Room Operators and Maintainers and Satellite Operations



Wideband Gapfiller Satellite Program

Wideband Gapfiller System (WGS), which will augment and eventually replace the communications capabilities of the existing Defense Satellite Communications System (DSCS) constellation.

The Air Force Satellite Control Network (AFSCN) is a global, robust, continuously operational network of ground stations, operational control nodes, and communications links that support launch, command, and control of various space programs managed primarily by the Department of Defense and other national security space organizations. In addition, it supports certain nonmilitary U.S. space assets, such as the weather satellites operated by the National Oceanic and Atmospheric Administration (NOAA), and select programs of allied nations. The Air Force Space and Missile Systems Center (SMC) manages acquisition, including development and sustainment of network capabilities.

The mission of AFSCN is to provide telemetry, tracking, and commanding as well as communications, selected mission-data dissemination, and data processing for operational missions and programs relating to research, development, testing, and evaluation of space systems. The history of AFSCN demonstrates the challenges of modernizing a fielded system that is in constant operational use. For more than four decades, program managers have been challenged by the need to insert more operationally effective and economical computing systems, communications equipment, and standards. Today, the network is undergoing a major upgrade of its remote ground stations while planning for increased interoperability with defense, civil, and commercial space control assets. The Aerospace Corporation has been a vital partner in the planning and evolution of the AFSCN since its early years and is helping to transition the network through its next phase of development.

Cognitive Analysis-One of Several Methods

- Formal collection of goals, actions, or events
- Formal probing questions for each node type
- First create a basic conceptual graph
- Second use probing questions
- Third validate the graph

Jonassen, D.H., Tessmer, M., Hannum, W.H. (1999). Task Analysis Methods for Instructional Design. Mahwah, New Jersey: Lawrence Erlbaum Associates, Publishers